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MIDDLE PARK INVENTORY ANALYSIS

K. Jon Ranson & Frank A. Itkowsky

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K. Jon Ranson and Frank A. Itkowsky

Final Report

Rocky Mountain Forest and Range Experiment Station
U.S. Forest Service Cooperative Agreement 16-630-CA
Principal Investigator: Dr. James A. Smith

June, 1977

Colorado State University
Department of Earth Resources
Fort Collins, Colorado 80523

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ABSTRACT

Remote sensing techniques provide a framework for assessing the nation's renewable resources rapidly and frequently. Rangeland and wildlife habitat form an important component of our natural resource base. As a specific example, the mule deer critical winter range and surrounding area of the Middle Park basin of Colorado provide a good study site for evaluating rapid, wide area remote sensing inventory techniques. This one-year study has investigated the application of machine-assisted analysis of digital LANDSAT imagery and underflight aerial photography to the problem of assessing range and wildlife habitat.

An experiment was made to survey the relationship between spectral response, specifically channel ratios, and biomass in a sagebrush community. Correlations of .76 to .83 were obtained between channel ratios and readings from a capacitance system for biomass measurement. However, correlations of .52 to .59 were obtained between either system and clipped and weighed biomass.

Computer-assisted classifications of August 15, 1975 LANDSAT MSS data were performed for the study area at a scale of 1:62,500 and for a subset of the area at a scale of 1:24,000. The 1:62,500 scale classification showed good general agreement with land cover patterns based on field studies and analysis of aerial photography. The larger scale classification was degraded to a large extent by the presence of mixtures. Quantitative evaluation of classification performance will be obtained in subsequent project tasks.

An initial example of a multi-level sampling scheme to estimate sagebrush acreage in the study site was reviewed and discussed. Further applications of the technique are currently under investigation.

ACKNOWLEDGMENTS

The research described in this report was supported under Cooperative Agreement 16-630-CA issued by the U.S. Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. Mr. Richard Francis was the technical monitor of the project. Cooperative assistance was also provided by the Colorado Division of Wildlife. The assistance of Dr. Lin Carpenter in defining categories, test areas and the supporting biomass data is particularly acknowledged. In addition, preliminary analysis of the Middle Park Basin was performed at the EROS Data Center in Sioux Falls, South Dakota.

Participating project personnel included Dr. James A. Smith, Department of Earth Resources and Principal Investigator; Dr. Charles Terwilliger, Department of Range Science and Co-Principal Investigator; Mr. Jon Ranson, Research Associate in the Department of Earth Resources; Mr. Frank Itkowsky, Graduate Research Assistant, Department of Earth Resources; Mr. Dan Kimes, Graduate Research Assistant, Department of Earth Resoruces; and Dr. J. K. Berry, formerly Research Associate, Department of Earth Resources. Administrative assistance was provided by Ms. Betty Gross. Secretarial and graphic services were provided by Ms. Kim Wagner and Ms. Chris Thornton. We would also like to acknowledge Mr. Jim Getter, Ms. Clara Frobig, and Ms. Lorraine Seger of the Colorado State Forest Service for their capable assistance during a ground reconnaissance survey of the test area.

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1.0 INTRODUCTION

The task charged to the U.S. Forest Service and other resource agencies of assessing the status of the Nation's renewable resources under PL 93-378, the Resources Planning Act, requires rapid inventory techniques which can be frequently updated and compiled with other data. Orbital, aerial and ground based remote sensing techniques provide a framework for this requirement.

An important component of the natural resource base is rangeland and wildlife habitat. The mule deer critical winter range and surrounding area of the Middle Park basin of Colorado provide a specific development and evaluation test site for rapid, wide area remote sensing inventory techniques.

The broad objective of this study as presented in the July 1976 Study Plan is to evaluate the application of machine-assisted analysis of digital LANDSAT imagery and underflight aerial photography to the problem of assessing range and wildlife habitat. There are three broad categories of the land area which relate to this task. These include: 1) cultural features, e.g., basic land use types such as transportation networks, urban development, and mining activities; 2) basic land cover vegetation categories such as forest, sagebrush, grassland, and others; 3) environmental factors such as snow cover, geologic material, and topography. In addition, there are several factors which may typify and quantify habitat types and characteristics, such as biomass, species composition, and phenological development.

1.1 Objectives

The objectives of the first year's effort as outlined in the Study Plan are: 1) to experimentally survey the relationsnip between spectral response and biomass in a sagebrush community, and 2) to determine the kind and extent of land use/vegetation cover (at a broad scale) that may be mapped using LANDSAT imagery. This report discusses the biomass experiment and the procedures and map products obtained from computer-assisted classification of LANDSAT MSS data for the study area at a scale of 1:62,500 and a portion of the critical deer winter range at a scale of 1:24,000.

Section 4 discusses multi-level sampling techniques which will be used in the future to quantitatively estimate land use and vegetation cover parameters.

In addition, a reconnaissance analysis of the Middle Park Basin was performed at the EROS Data Center, Sioux Falls, South Dakota early in the study (Figure 1). Primary objectives of this activity included the desire to obtain an early appreciation of class separability and to become familiar with the state-of-art techniques available for multispectral classification. In the work reported here, only results obtained with the more classical batch-oriented processing programs available at Colorado State University are included.

1.2 Study Site Description

The study site is located within the Middle Park basin in north-central Colorado and covers an area of 1,567 km^2 (1,605 sq. miles) (Figure 2) (Plate 1).

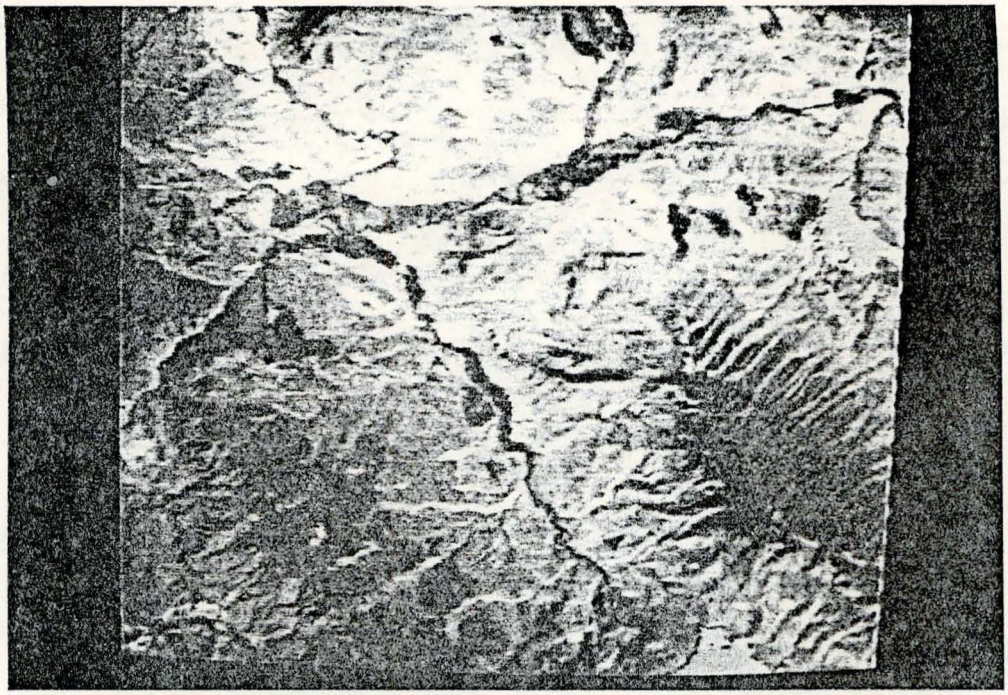


Figure 1. Initial theme classification map obtained from the EROS Data Center Image Processing Facility. Water has been coded blue; coniferous forest as bright red. Remaining image tones are a false-color rendition of the LANDSAT scene.

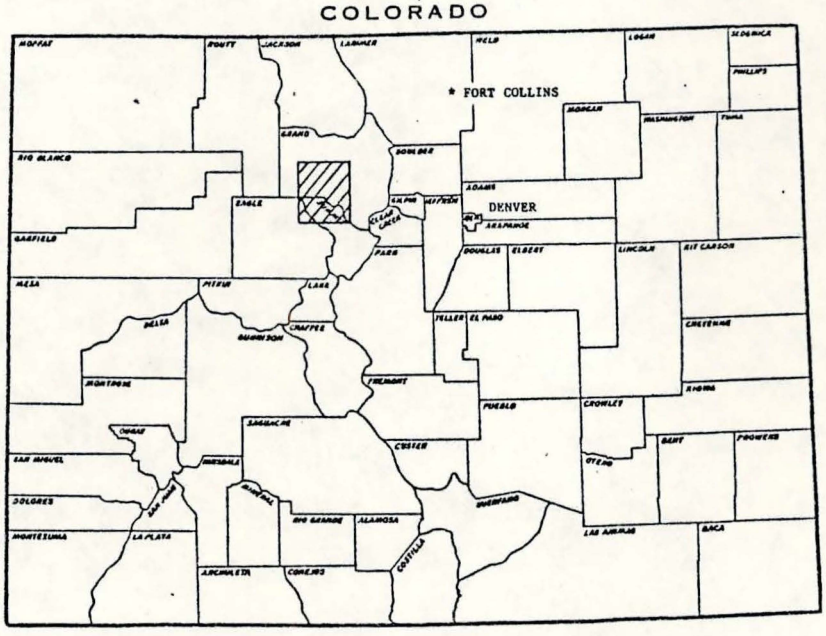


Figure 2. Map of Colorado showing Middle Park Study Site as shaded area.

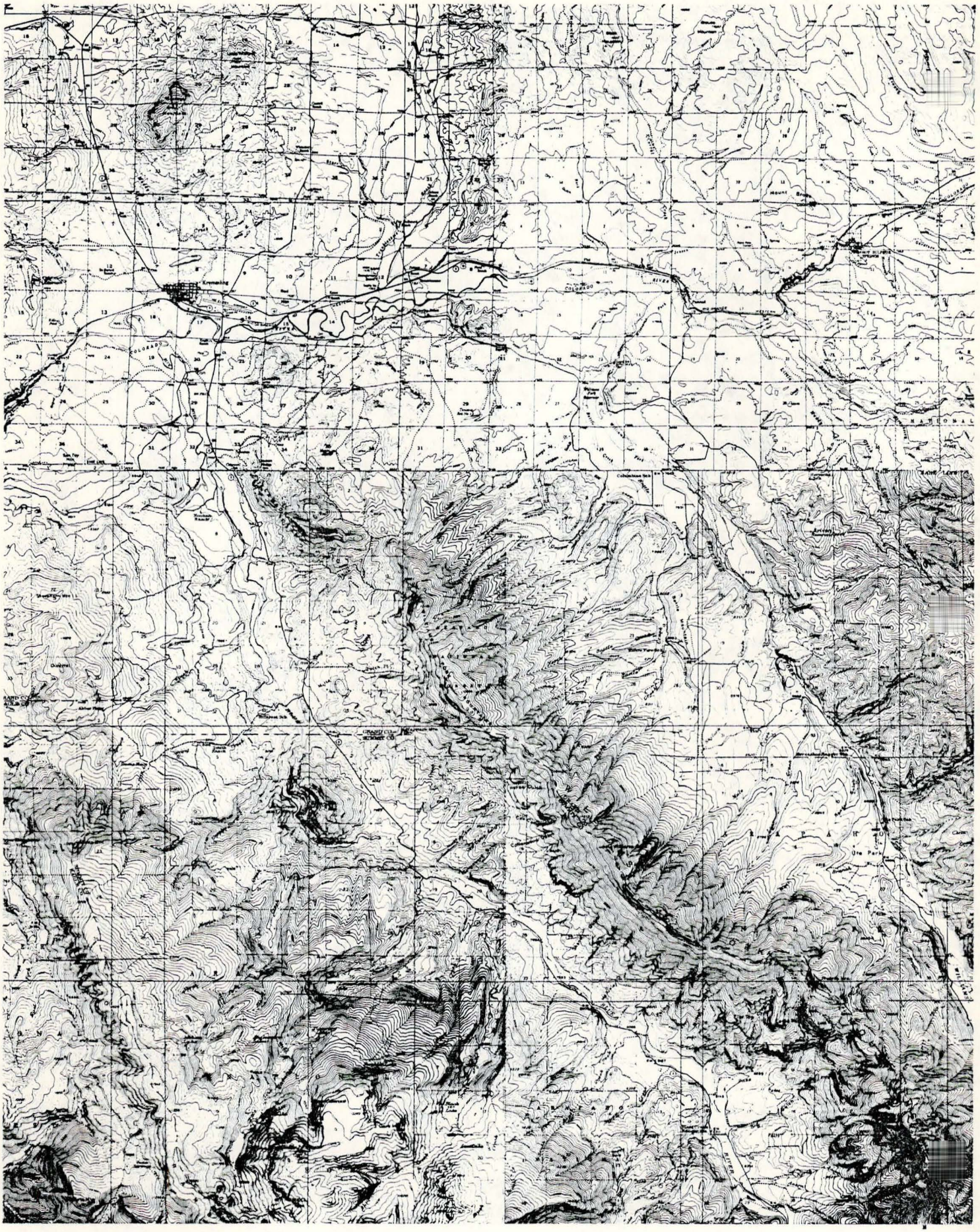


Plate 1. Map of Middle Park Basin study area.

The area is bounded by 40°08'N and 39°45'N latitude on the north and south and 106°03'W and 106°28'W longitude on the east and west, and includes portions of Grand, Summit and Eagle counties. The prominent cultural features in the area are the towns of Kremmling and Hot Sulphur Springs and Williams Fork Reservoir and Green Mountain Reservoir. Major physiographic features are the Colorado and Blue Rivers, Wolford Mountain, and Williams Fork and Gore Mountain Ranges. Elevations range from 4,125 m (13,534 ft.) at the summit of Mt. Powell in the extreme south edge of the area to 2,194 m (7,200 ft.) at the bottom of Gore Canyon where the Colorado River exits the study area on the western boundary.

The important vegetation types in the area include shrubs such as several species of sagebrush (Artemisia spp.), rabbitbrush (Chrysothamus nauseousus), service berry (Amelanchier alnifolia), greasewood (Sarcobatus vermiculatus), bitter brush (Purshia tridentata) and Rocky Mountain juniper (Juniperus scopulorum); grasses include bluegrass (Poa spp.), wheatgrass (Agropyron spp.), and fescues (Festuca spp.); forest types consist mainly of lodgepole pine (Pinus contorta), quaking aspen (Populus tremuloides), Engelmann spruce (Picea engelmannii) and subalpine fir (Abies lasiocarpa). With the addition of low, mid and high elevation bald ridges, the grasses and shrubs make up the initial mule deer habitat types initially defined by Terwilliger (1977) for the Middle Park area.

2.0 EXPERIMENT - BIOMASS VS. SPECTRAL RESPONSE IN A SAGEBRUSH COMMUNITY

2.1 Background

The weight of aboveground parts of live vegetative material (biomass) is an important indicator of the characteristics of a plant community. It is used by rangeland resource managers to estimate animal carrying capacity, quantify production and utilization, and evaluate experimental treatments. Several studies have indicated that it is possible to estimate in situ biomass in natural grasslands and rangelands using spectral measurements (Pearson and Miller, 1972; Tucker et al., 1973; Tucker, 1973). These and other studies have demonstrated a relationship between the weight of standing green plant material and the ratio of reflected solar radiation centered at .6750μm and .8000μm in primarily shortgrass prairie communities.

Pursuant to the objectives of this study an experiment was performed during August 1976 to determine if spectral ratio techniques could be used to estimate biomass in a sagebrush community. The study site was within a Colorado Division of Wildlife deer habitat study area 11 miles east of Kremmling, Colorado.

2.2 Experimental Procedure

The experiment consisted of using a Neal Electronics capacitance meter, the CSU Scene Recording Radiometer (SRR), and a clip and weigh techniques to estimate biomass.

The capacitance meter allows a non-destructive sampling technique that estimates biomass as a function of leaf water (Neal and Neal, 1973).

It utilizes the concept that a significant difference exists between the dielectic constant of air and the dielectic constant of leaf water present in vegetation. The capacitance measured is proportional to the leaf water present between the device's capacitance probes.

The Scene Recording Radiometer (SRR) is a six-band spectral radiometer which supplies a photographic record of the field-of-view (Berry et al., 1977). Four narrow band filters centered at .5000μm, .6750μm, .8000μm, .9600μm, and two broad band filters with wavelength intervals of .6 - .7μm, and .8 - 1.1μm were selected for the study. Spectral irradiance measurements were obtained, using a $BaSO_4$ reference panel before and after spectral radiance measurements were taken.

Twenty-six plots were selected for analysis. Each plot was defined by a 1' x 2' (.186m^2) rectangle. The capacitance meter was positioned over each plot and readings recorded (Figure 3). Immediately following, the SRR was set up and optically aligned over the plot. This was accomplished by using a rectangular field-of-view mask of the same proportions as the sample plots. Spectral irradiance and spectral radiance measurements were taken (Figure 4). Immediately following the SRR determination, Division of Wildlife personnel clipped each plot and sorted the plant material into species which were then placed in paper bags for later analysis.

2.3 Experimental Results

Table A1 in Appendix A lists the SRR data and capacitance meter readings acquired for the 26 sample plots. Table A2 shows the weight (in grams) of each vegetation type for 15 1' x 2' plots which were

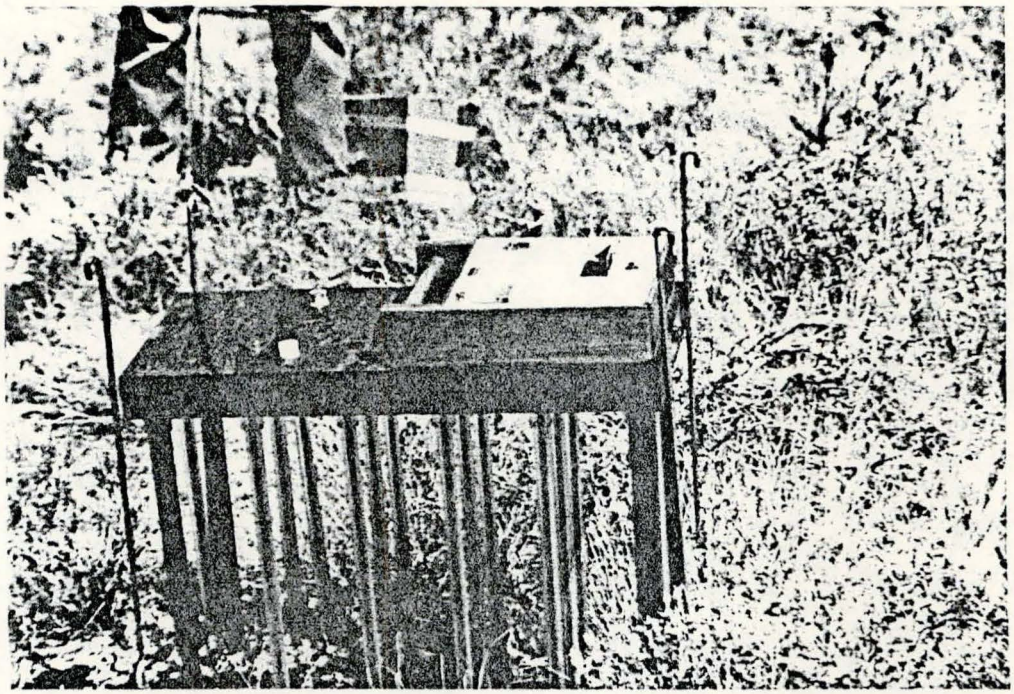


Figure 3. Electronic capacitance meter used for biomass experiment.

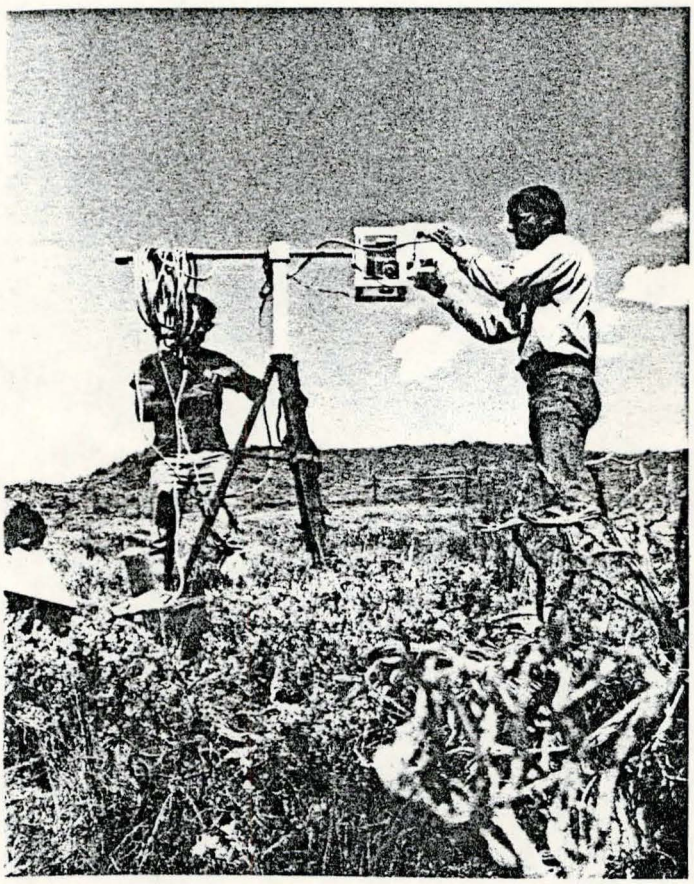


Figure 4. Scene Recording Radiometer set up over sagebrush community.

provided by the Division of Wildlife. These data were used to form several linear regression relationships as described below.

The first regression performed investigated the relationship between the ratio of narrow bands .8000μm and .6750μm and biomass determined by the capacitance meter. Data for 26 plots were used in the analysis. The second regression showed the relationship between the ratio for spectral reflectance of the two broad band filters, .6 - .7μm and .8 - 1.1μm. Data for the same 26 plots were used to develop this regression. Finally, regressions were performed using the clippped plot data as "true biomass" and SRR and capacitance meter data as biomass predictors. We attempted to develop regression relationships for the biomass of each vegetation type and the total of all biomass using combined sample plot data. Table 1 shows the regression equations developed and the coefficient of determination (R^2) for each of the attempted analyses.

Table 1. Results of linear regression for spectral ratio data vs. capacitance data, and spectral ratio vs. clip and weigh biomass data.

Problem	No. of Sample Plots	R^2
.8000μm/.6750μm vs. Capacitance	26	.58
.8 - 1.1μm/.6 - .7μm vs. Capacitance	26	.58
.8000μm/.6750μm vs. Total Biomass*	15	.27
.8000μm/.6750μm vs. Artemisia Biomass*	15	.35
.8000μm/.6750μm vs. Capacitance	15	.69

*Biomass was determined by clip and weigh technique

The results show a possible relationship between ratioed SRR data and capacitance meter data. The poor coefficient of determination between clipped plot biomass and SRR and capacitance data may be explained, in part, by deviations from the normal in the clipping and weighing process (Carpenter, 1976). That is, in this experiment none of the plots were clipped until both SRR and capacitance readings had been obtained for all 26 plots. We attempted to develop regression equations between spectral ratio data and individual vegetation types, but correlations were too poor to produce any results, except in the case of Artemisia.

3.0 PROCEDURE FOR CLASSIFICATION OF LANDSAT MSS DATA FOR VEGETATION/ LAND USE COVER

A portion of August 24, 1975 (Frame No. 5127-16532) LANDSAT MSS data covering the study site was selected for computer-assisted classification on the CSU CDC 6400. CIR aerial photography at scales of 1:65,000 and 1:130,000 (U-2 Mission #76-096) were used as an aid in the classification.

The computer-assisted classification procedure consists of preprocessing the data, selecting the categories for the classification scheme, obtaining a set of representative statistics for each category, classifying the LANDSAT MSS data, and evaluating the performance. This sequence is outlined as a flow diagram in Figure 5.

The following discussion refers to the procedure undertaken while classifying the 1:62,500 study area. Differences in the procedure for the intensive study area (1:24,000) will be noted in a separate section.

3.1 Data Preprocessing

The data preprocessing procedure is outlined in Figure 5. The first step is to run the program ERTS to convert raw LANDSAT data on a CCT to the format used by the programs at Colorado State University. Only one tape can be input at a time and since the study area spans two tapes the program was run twice. The output of ERTS and of all succeeding programs was put on disk. The output of these two runs (files ONE and TWO) are combined using the program TWOTAPE.

The program ROTATE was run to geometrically correct the data, including conversion to the appropriate scale (Anuta, 1973). Separate

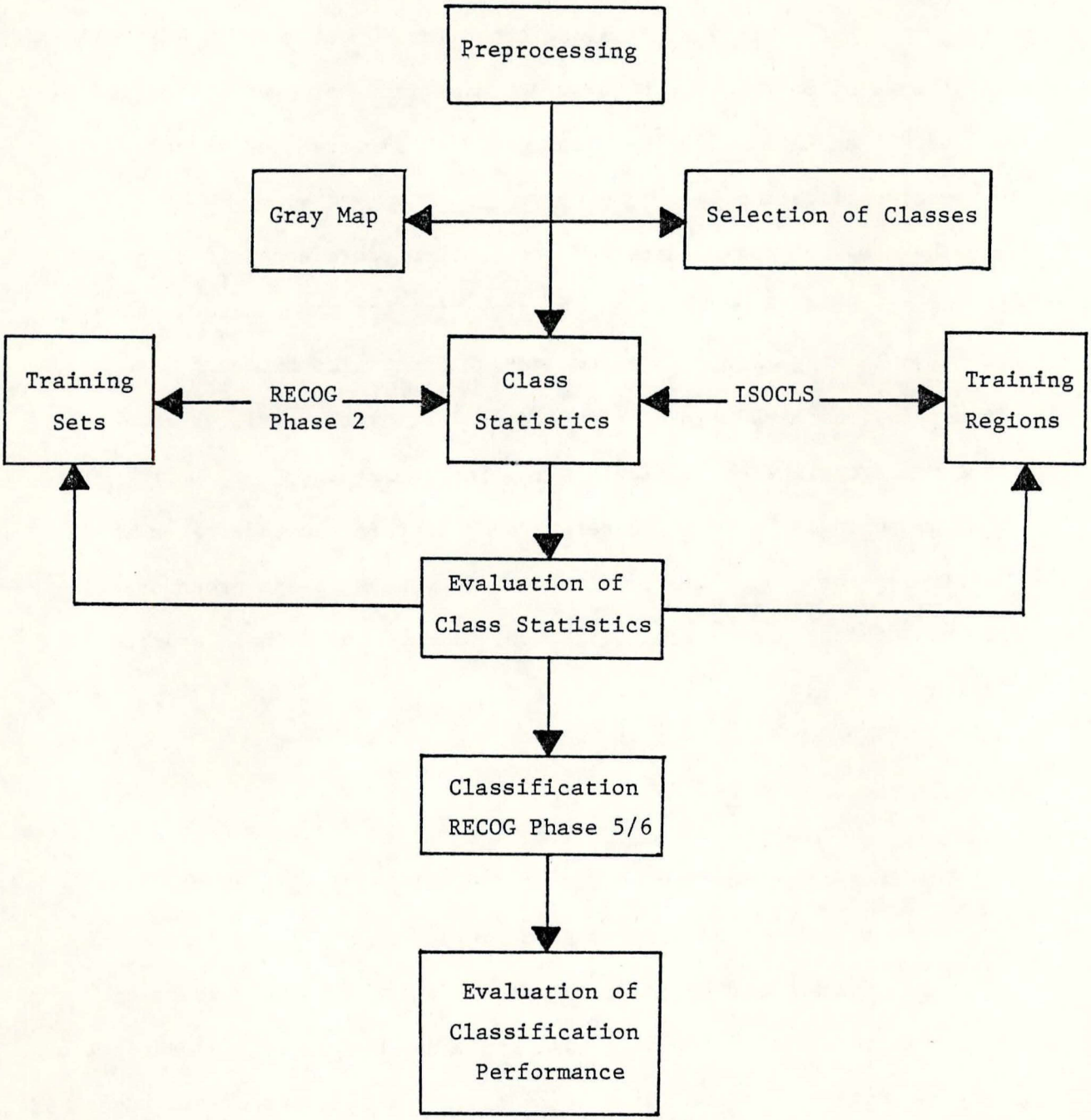


Figure 5. Flow diagram of computer-assisted classification procedure for Middle Park Inventory Analysis.

runs were made converting the appropriate area to scales of 1:62,500 and 1:24,000. The scale of 1:62,500 was chosen because that is the scale of the existing topographic maps for the area. The scale of 1:24,000 was chosen for the intensive study area because it is at that scale that work is normally done with LANDSAT data. In actuality, because of the large amount of data for the 1:62,500 study area, four separate runs were made for this scale, converting one channel at a time. The four outputs were combined, two at a time, using the program MERGE.

The program FILTER was used to "smooth out" (i.e., reduce effects of atmospheric and sensor noise) the data. This program calculates a new value for each pixel by taking a weighted average of the point and the eight surrounding points (Maxwell, 1976).

The geometrically corrected, filtered data contained in file FIVE was then used for the classification procedure (RECOG). To be used by the program ISOCLS (Minter, 1972), the data had to be converted to the correct format. The program JSPREP (a revision of the program PREPIT) (Merritt, 1977), was used to accomplish this.

3.2 Class Determination/Description

The two main considerations in determining the ground cover classes to be used in the classification were: 1) what types of ground cover exist in the Middle Park study area? and 2) what differences in ground cover can be discriminated using the aerial photography and LANDSAT data?

As an initial guide, the system of classes used by the Colorado State Forest Service for ground cover mapping was used. Of the 21

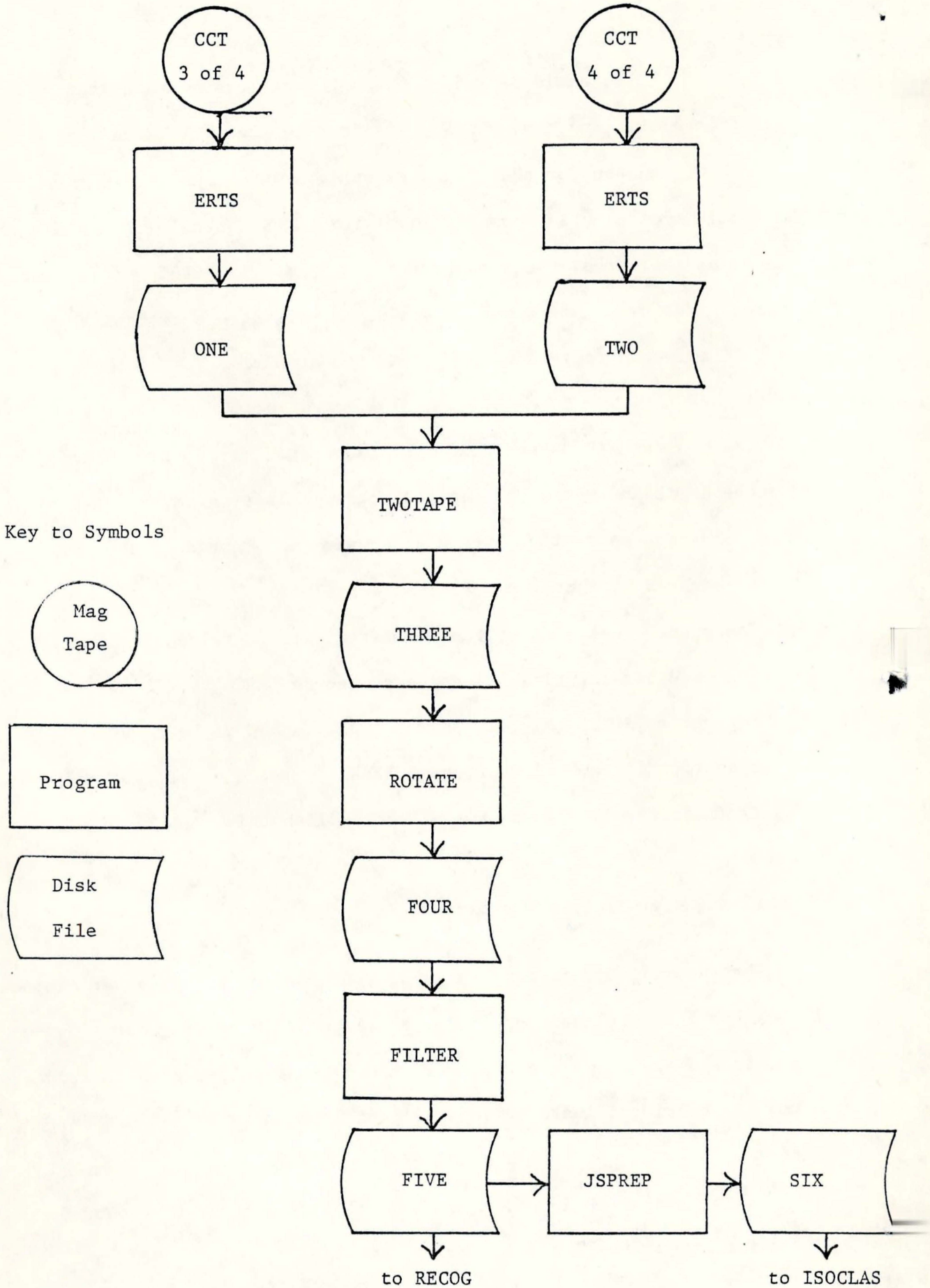


Figure 6. Preprocessing flowchart.

classes in the C.S.F.S. system, 13 were found to exist in Middle Park in stands of a size measurable by remote devices. This was determined in a pre-classification reconnaissance trip to the study area. Based on the second consideration, some classes were combined to come up with the eight classes used in the final classification. The classes selected for analysis were:

1) Water - Lakes, reservoirs, and rivers. Williams Fork Reservoir and Green Mountain Reservoir are the two prominent examples of this class in the study area.
2) Coniferous Forest - Vegetation cover on mountain slopes consisting primarily of pure and mixed stands of lodgepole pine (Pinus contorta) and Engelmann spruce/subalpine fir (Picea engelmannii/Abies lasiocarpa). Also included in this class could be stands of mixed conifer and aspen and dense stands of pinon/juniper. Good examples of this class are shown in Figures 6 and 11.
3) Deciduous Forest - Vegetation cover on mountain slopes and along rivers consisting of aspen and cottonwoods (Populus spp.). Dense stands of willows (Salix spp.) might also be included in this class. An example of this class can be seen in Figure 6.
4) Mountain Shrub - Vegetation cover consisting of deciduous shrub species, e.g., serviceberry (Amelanchier alnifolia), snowberry (Symphoricarpos spp.), sage (Artemisia spp.) and small aspen clumps (Populus tremuloides). Open and mixed stands of juniper (Juniperus spp.) would also be an example of this class. Figure 8 shows an actual training field for this classed used for the computerized classification.

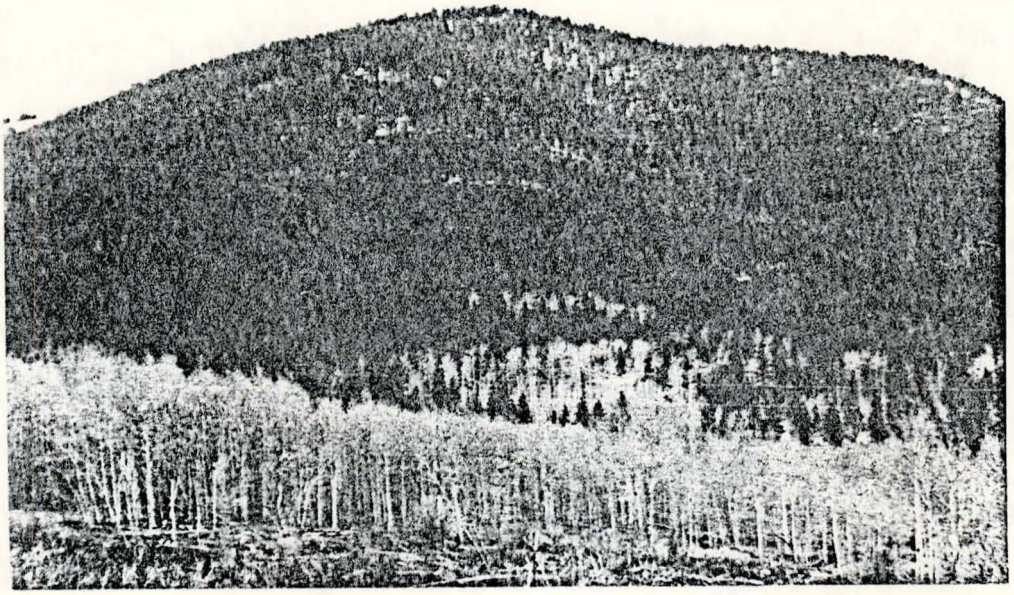


Figure 7. Scene showing a stand of lodgepole (coniferous forest class) and quaking aspen (deciduous forest class) in foreground.

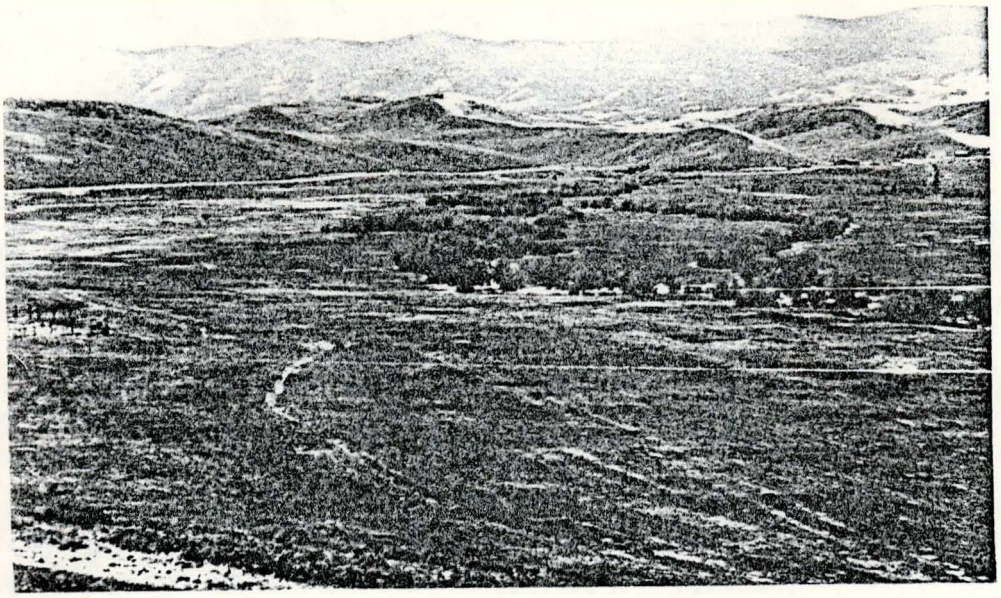


Figure 8. This scene depicts irrigated grass (meadow class) with phreatophytes (deciduous class) growing along the stream channel. Also present are coniferous forest on slopes in background, aspen and sage on middleground slopes and isolated areas of mountain grass (light colored areas on ridge tops).

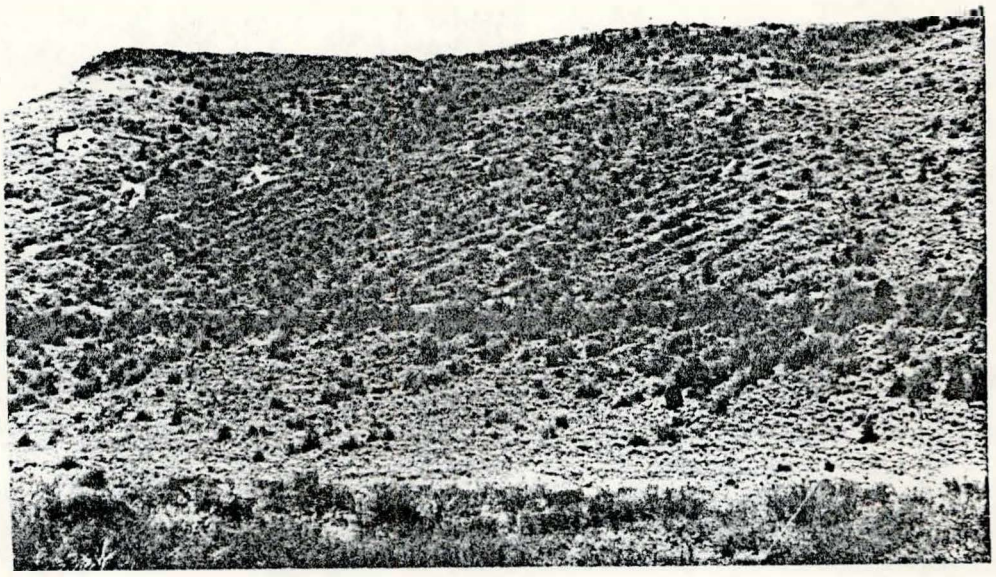


Figure 9. Hillslope showing typical mountain shrub class. Note the presence of sagebrush intermixed with the various shrub species.

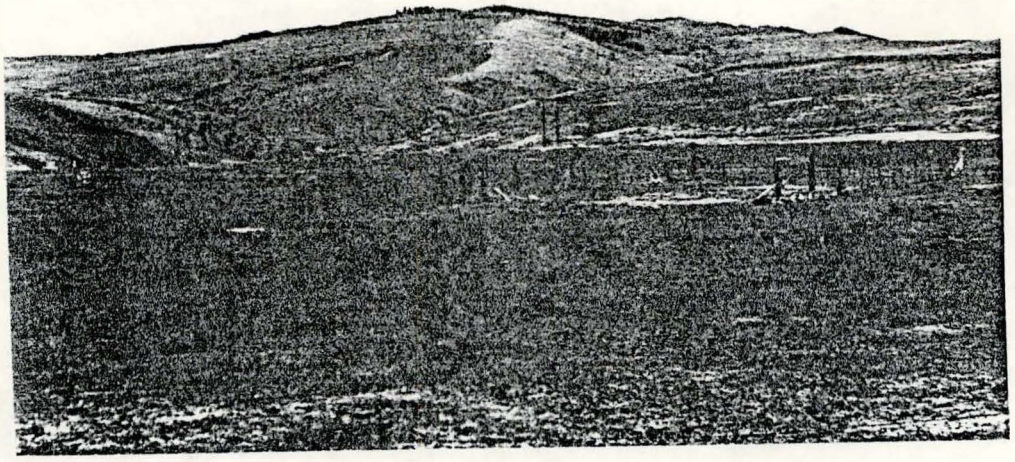


Figure 10. An irrigated field is shown in the foreground. Sage, with patches of mountain grass, aspen and conifer covers the hills in the background.

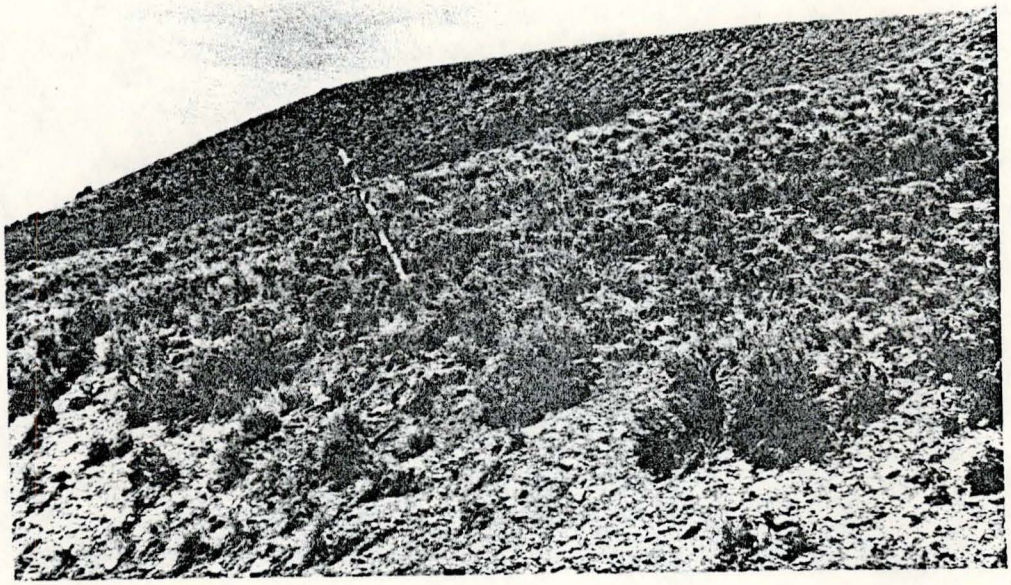


Figure 11. Shown here is a typical slope representing the sage class. The bare area in the foreground is part of a road cut and is included in the non-vegetated/disturbed class.

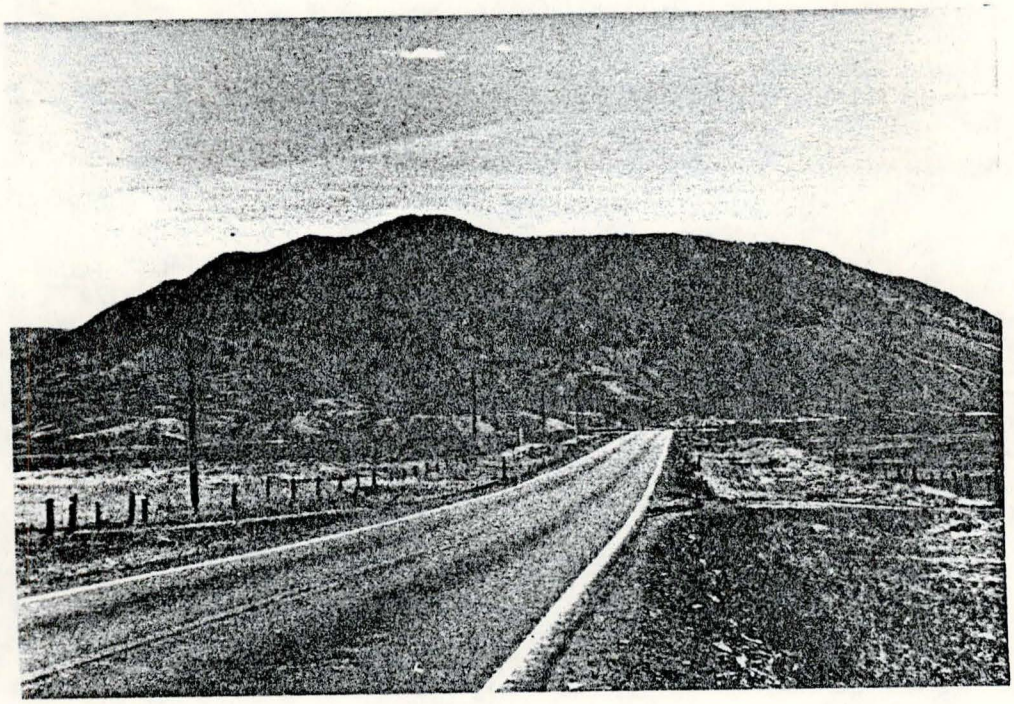


Figure 12. Northeast side of Wolford Mountain is seen in the background showing striking interface of sage and coniferous forest.

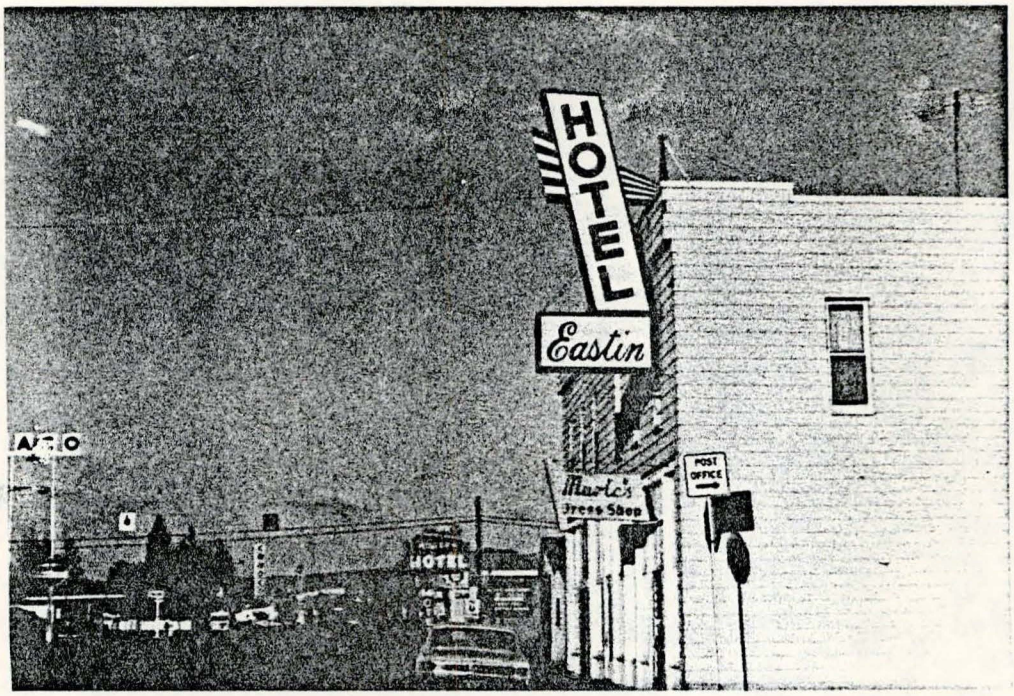


Figure 13. Downtown Kremmling, Colorado represents urban development (Non-vegetated/disturbed class).

5) Meadow - Vegetation cover on hayfields, pastures, and other wet fields along streams, irrigated upland fields, and lush mountain meadows, consisting mainly of grass (Carex spp., Juncus spp., etc.). An example is shown in Figure 7.

6) Mountain Grass - Vegetation cover on non-irrigated upland fields consisting mainly of grass and forbs (e.g. penstemon). It is found largely on ridge tops as seen in Figures 7 and 9.

7) Sage - Vegetation cover consisting mainly of sage (Artemisia spp.) intermixed with Agropyron spp., Poa spp., and Festuca spp. Figures 9, 10, and 11 show this class.

8) Non-vegetated/disturbed - Bare rock and soil, large buildings, paved areas and other areas without vegetation. Also included are areas of sparse vegetation (sage or grass) consisting mainly of rock, soil, or dead vegetation. Examples are given in Figures 10 and 12.

3.3 Signature Extraction

Computer-assisted classification was performed for the two study areas using the set of programs collectively called RECOG (Smith et al., 1972). The first step was to use the program PHASE 1 to produce a graymap of the area for each LANDSAT channel. The corrected and filtered data produced in the preprocessing stage is used as input to PHASE 1 and succeeding phases.

Two different approaches were used to obtain statistical signatures for the eight land cover classes. One used the program PHASE 2 of RECOG and the other used the program ISOCLS (Minter, 1972). In using PHASE 2,

training fields thought to be representative of each of the eight land cover classes were delineated on the graymap. The aerial photography was used to locate areas large enough and homogeneous enough to be used as training fields. The program ISOCLS provided an unsupervised clustering type of classification for the area. Analysis of this classification map was used in an attempt to extract signatures for some of the classes. In practice it was found that a working familiarity with using PHASE 2 and a lack of familiarity with the analysis required to use ISOCLS effectively made the former the easier and more useful approach. ISOCLS was used, however, to obtain class signatures where adequate training fields (areas of sufficient size and homogeneity) could not be found. This was the case with the non-vegetated/disturbed class, which is inherently heterogeneous. ISOCLS yielded an apparent bare ground cluster, and using the mean and covariance matrix of this cluster for the class signature in RECOG classification gave satisfactory results.

In using PHASE 2 to extract signatures an apparent bimodality for the classes deciduous and sage was cause for splitting each into two subclasses. The subclasses were combined after final classification (PHASE 5) for the final display (PHASE 6).

The spectral signature statistics were evaluated by analyzing the relationship of the class data clusters to one another in two-band combinations. A useful method for accomplishing this is to portray the data as an ellipse of concentration with the slope determined by the principal components (eigenvectors) and the axes representing the eigenvalues of the two-band variance-covariance matrix (Davis, 1973). The resulting ellipse shows the data cluster in two-space and includes

66.7% of the class data for those spectral bands.

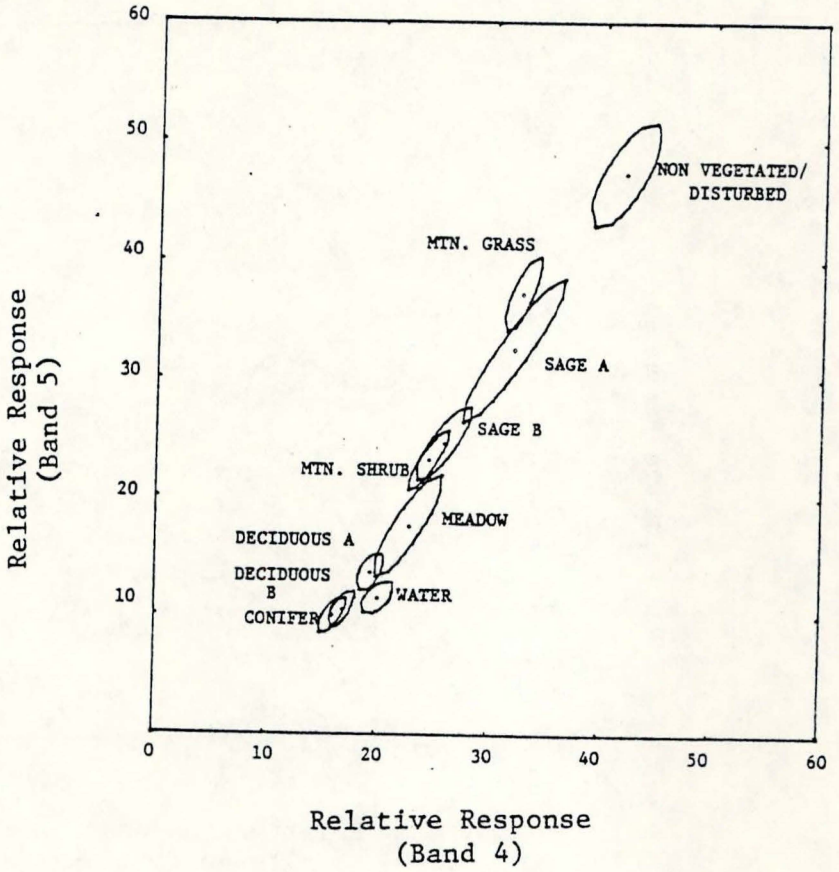
When the ellipses of concentration for each class are compared for any two-band combination, the spectral separability of the classes can be inferred. Figure 13 shows a series of ellipses of concentration plots for the class statistics in all possible two-band combinations. Upon inspection of these plots, several characteristics of the class spectral signatures are readily apparent. As expected, data for bands 4 vs. 5 and 6 vs. 7 are highly correlated. Data clusters for water, non-vegetated/disturbed, mountain grass and sage A are essentially spectrally distinct for all combinations. Sage B, deciduous B and conifer are spectrally distinct in all combinations but bands 4 vs. 5, meadow and deciduous A, have some overlap of data clusters in all band combinations. Due to the coarse resolution of the 1:62,500 scale data and the difficulties encountered in locating other representative training sets for the deciduous A class, the signature set was left intact for the initial classification of the LANDSAT MSS data.

3.4 Classification and Display

Once the signature extraction/evaluation has been performed the final classification and display is done. Classification is done with the program PHASE 5, which produces an output file of classified data. The program PHASE 6 reads this file to produce the final classification map.

Since analysis of the final display provides perhaps the best method of signature evaluation, the process of signature extraction, evaluation, classification, and display proved to be an iterative one.

a.



b.

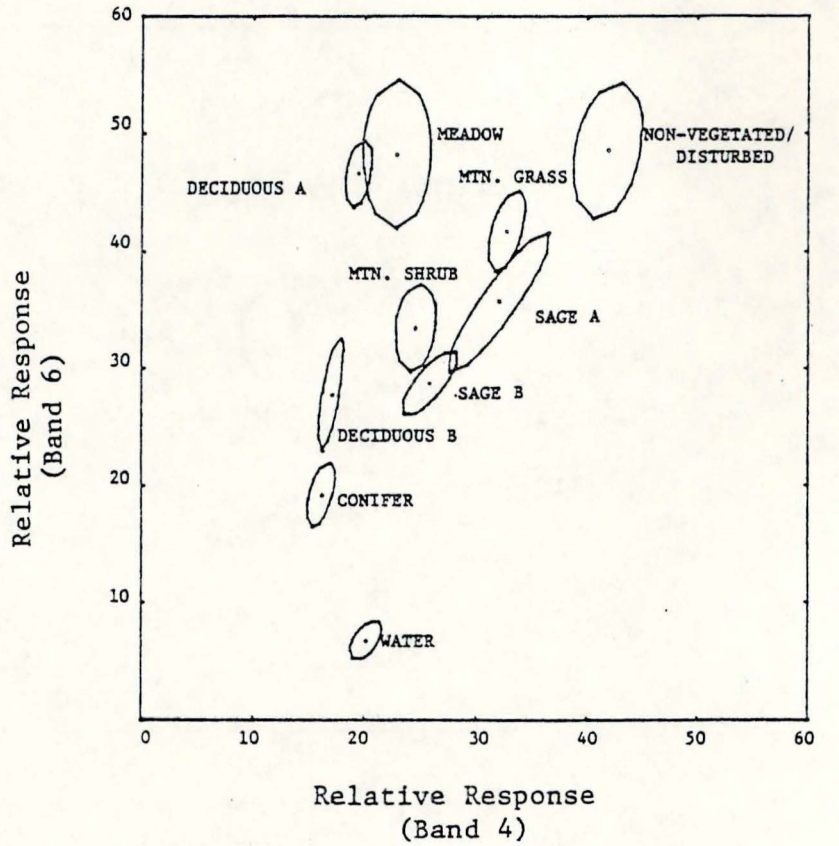
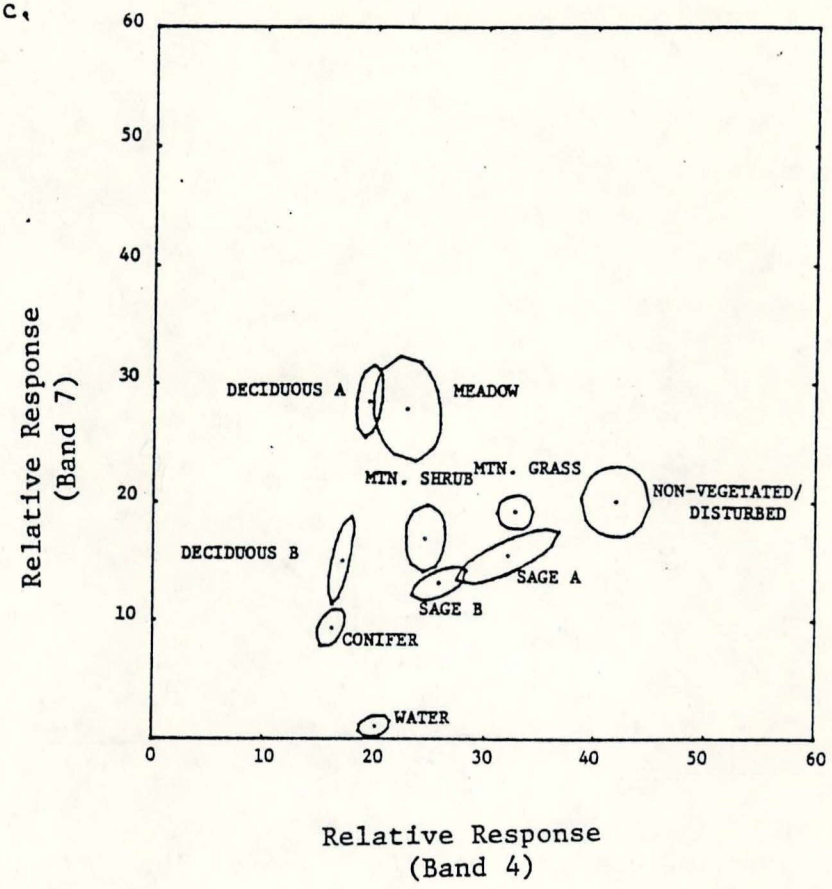


Figure 14. Ellipses of concentration in two spectral spaces for

c.



d.

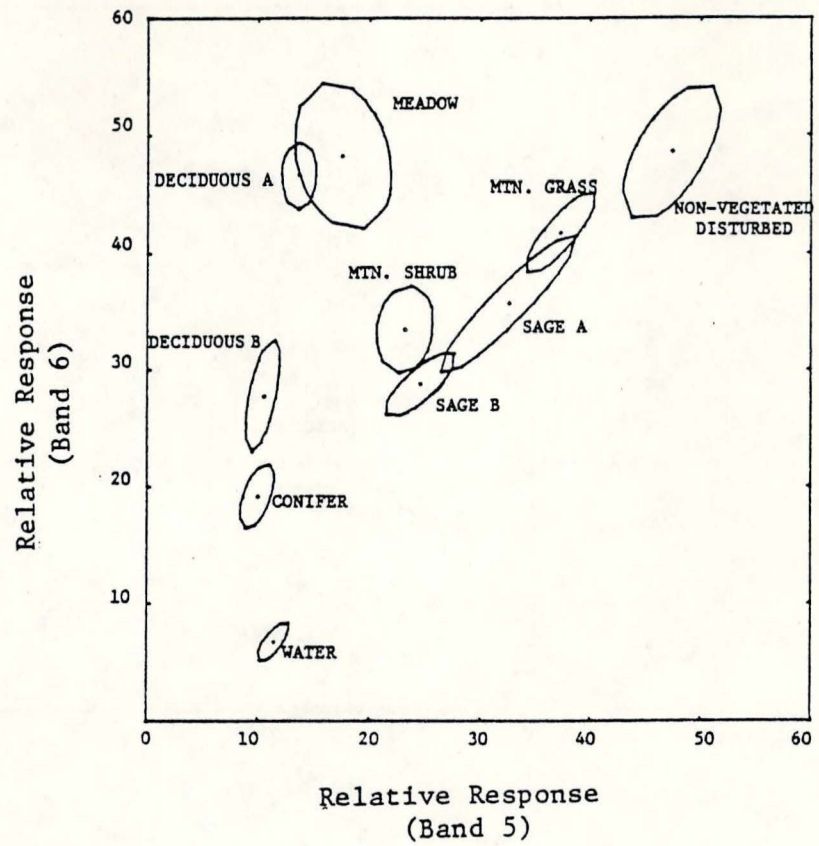
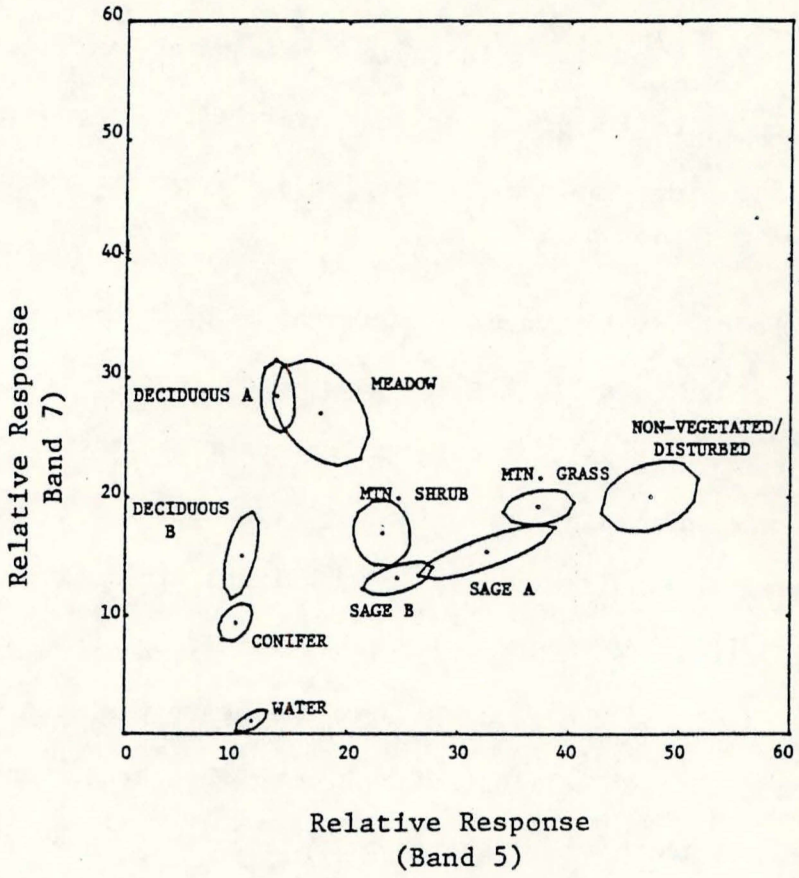


Figure 14. (continued)

e.



f.

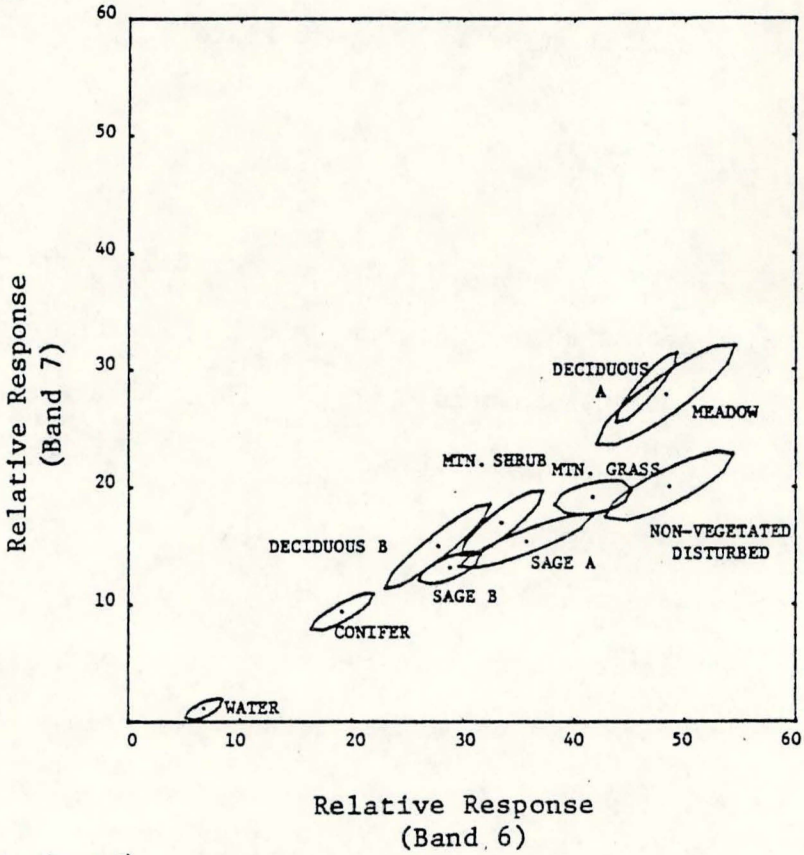


Figure 14. (continued)

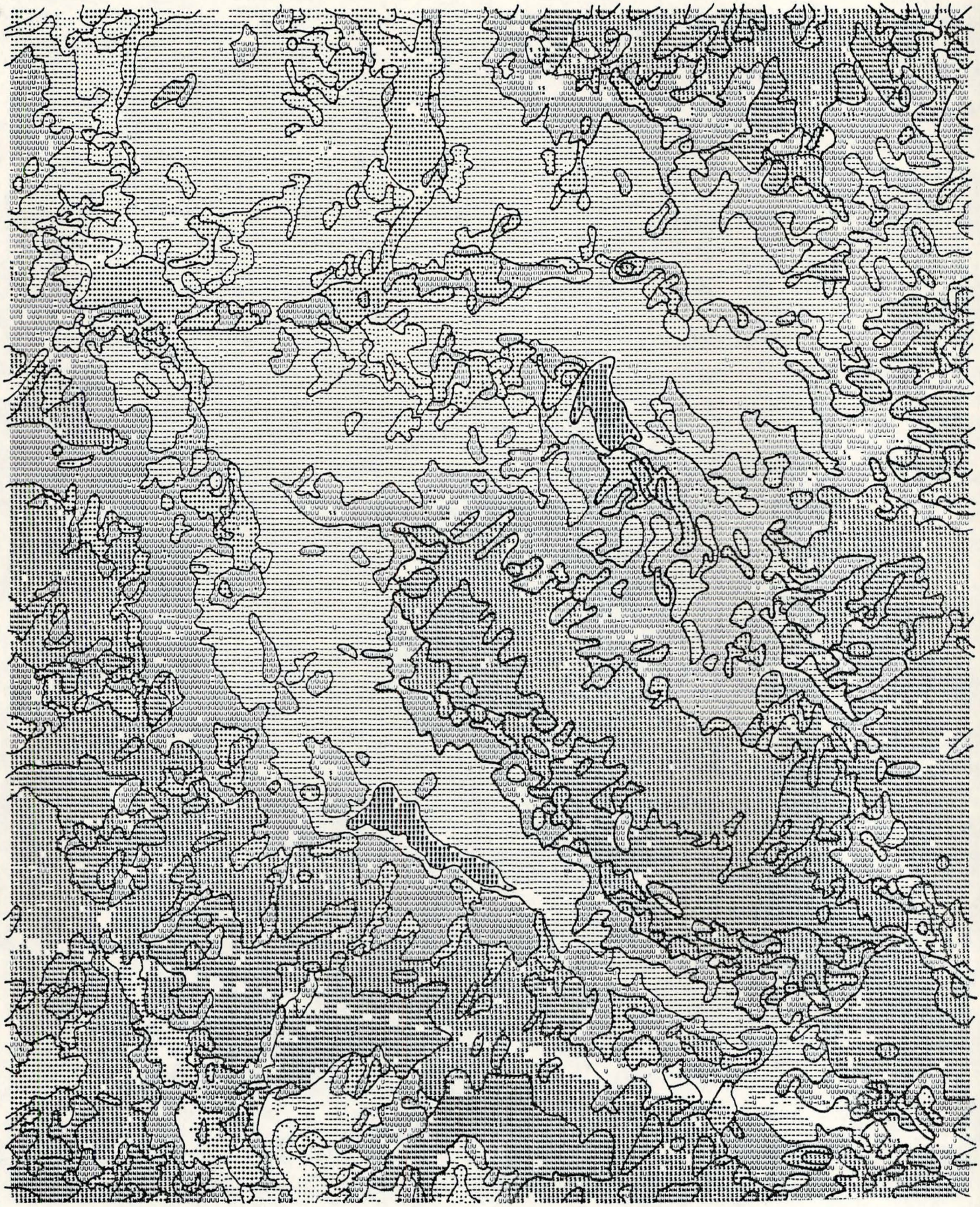
It did require, however, considerable human and computer time to perform one iteration of this process, so that every effort was made to obtain good class signatures before the final classification and display were performed.

The form of display used is a graymap similar to that produced in PHASE 1. Eight gray levels are used, each corresponding to a land cover class. Each pixel, or printed character, on the classification map represents an area of approximately 19.8 hectares (8 acres). Land cover classes were delineated by drawing lines around groups of pixels of the same class. An arbitrary rule of requiring at least four contiguous pixels of the same class to delineate the area was followed. Thus the minimum area delineated was about 80 hectares. Based on this delineation, an acetate overlay was prepared with each of the eight land cover classes color-coded. This overlay is meant to be used in conjunction with the topographic maps of the area. A reduced representation of the classification is shown in Plate 2.

3.5 Evaluation of Results

A quantitative evaluation of class separability was made by making up a confusion matrix to show how the training fields were classified. Confusion matrices are shown in Table 2. The non-vegetated/disturbed class is not shown in the matrices because, as previously explained, training fields were not used to obtain the class signature.

It can be seen that classification of the training fields was better than 90% correct for all classes except mountain shrub and meadow. In the case of mountain shrub, this is because of the small size of the training field (only two points were misclassified resulting



Key: W Water N Coniferous Forest S Deciduous Forest - Sage
U Mountain Shrub + Mountain Grass * Meadow . Disturbed

Plate 2. Land cover classification of study area.

Table 2. Accuracy of Training Field Classification - 1:62,500.

Points Classified As:

Training Field	Conif.	Decid.	Mtn. Grass	Mtn. Shrub	Meadow	Sage	Water	Unclassified
CONIFER	84					3		2
DECIDUOUS		69			1			
MTN. GRASS			17	1				
MTN. SHRUB				10		2		
MEADOW		24		10	93			
SAGE			1	3		179		3
WATER							118	8

Percent Classified As:

Training Field	Conif.	Decid.	Mtn. Grass	Mtn. Shrub	Meadow	Sage	Water	Unclassified
CONIFER	94.4					3.4		2.2
DECIDUOUS		98.6			1.4			
MTN. GRASS			94.4	5.6				
MTN. SHRUB				83.3		16.7		
MEADOW		18.9		7.9	73.2			
SAGE			0.6	1.6		96.2		1.6
WATER							93.7	6.3

in an accuracy of 83.3%). In the case of meadow, 18.9% of the points were misclassified as deciduous and 7.9% as mountain shrub. The confusion with deciduous can be explained by looking at the ellipses of concentration (Figure 13). In each plot the ellipse for the meadow class is relatively large and overlaps the ellipse for the deciduous A class.

A qualitative analysis of the total scene classification was made by using the aerial photographs and a familiarity with the study area to test the classification results.

The observation was made that the classification map shows a definite gradation from sage to mountain shrub to deciduous forest to coniferous forest. This gradation is obviously related to elevation. In actuality there is no sharp demarcation between the areas occupied by these vegetation classes. The sparse sage of drier lower elevations becomes denser and mixed with other shrub species at higher elevations. At higher elevations aspen gradually becomes more prominent. At still higher elevations the aspen mixes with pine, spruce, and fir and eventually gives way to pure stands of spruce/fir.

Another observation is that large areas in the northern half of the map were classified as non-vegetated/disturbed. Many of these areas consists of sage and/or grass that is too sparse to be classified as such. Figure 11 shows such an area in the left foreground. It is an area of dried, brown grass which was classified as non-vegetated/ disturbed rather than as mountain grass or meadow.

Generally speaking, the classification map appears to provide a rough idea of the acreage and location of the land cover classes used. The small scale of the map would limit its use in detailed analysis of

the area, but for an area the size of this study area it appears to be good compromise between a more detailed and expensive map and one which is so gross as to provide little or no information.

3.6 Classification Procedure for Intensive Study Area

Program ROTATE geometrically corrects data and converts it to a given scale. Separate runs of the program were made to convert the entire study area, termed the intensive study area, to a scale of 1:24,000. The consideration in selecting the subset of the study area to use as the intensive site was to include a large portion of the mule deer winter range. The intensive site includes Little Wolford Mountain to the north, the Colorado River to the south, Big Muddy Creek to the west, and extends almost to Troublesome Creek on the east. After ROTATE, preprocessing as outlined in Figure 4 was the same for both study areas.

One major difference in the classification procedure for the two study areas was that although the final display for the broad study area used filtered data, the signature extraction procedure used unfiltered data. Filtered data were used for both final display and signature extraction for the intensive study area. No differences in performance or accuracy were noted between the two approaches. To precisely compare the two methods one would have to process the same data in each case.

The same set of land cover classes was used for both study areas. The one exception was that the deciduous forest class was not included in the intensive study area simply because there are no significant deciduous stands in the area. Small stands of aspen which might occur, along with riparian cottonwoods and willows, were classified as

mountain shrub.

Because there are no maps of the area at a scale of 1:24,000 available, no overlay of the final classification was made.

3.7 Evaluation of Results - 1:24,000 Classification

As in the case of the 1:62,500 scale classification, the only quantitative evaluation performed for the 1:24,000 classification was analysis of training set class separability. These results appear in Table 3 as a confusion matrix. The signature for grass was obtained from the 1:62,500 data so it is not included in the matrix. Meadow, sage and non-vegetated/disturbed training sets showed classification accuracies of 94%, 93% and 88% respectively. Although not outstanding, these results were adequate within the limits of time and ground control information. Conifer and shrub training area results were quite poor.

Interestingly enough, a section of the Colorado River which showed up well on our graymap and on a June 26, 1976 color composite LANDSAT image was classified as mainly shrub with some conifer. We attempted to extract a water signature from this part of the river but were frustrated by spectral statistics uncharacteristic of water (e.g., relatively high response in the near infrared bands). Consequently, we used a signature for water obtained from the 1:62,500 data, however, no points in the intensive study area were classified as water using this signature. Upon examination of a 1:65,000 color IR photograph of this section of river, it was found that where meadow grasses made up the shoreline vegetation the points were misclassified as shrub.

Where deciduous shrubs composed the bordering vegetation, the points were left unclassified. Ellipses of concentration were plotted for the water signature (extracted from the river), shrub and meadow. For comparison purposes the ellipse for the 1:62,500 water signature was also plotted. Figure 14 shows the ellipses plot for bands 5 vs. 6 and 6 vs. 7. Overlap of the shrub and river water ellipses is apparent in both cases. It is possible that this overlap is due to a mixture of some proportion of water and meadow that approximates the spectral signature for shrub.

A similar analysis was performed for conifer and shrub since the classification map showed gross misclassifications of conifer as shrub. Again it appears that in areas where there is a mixture of conifer and sage or grass, the resulting MSS response may approximate that of shrub. To verify these observations, additional aerial photographs will be acquired and these and other areas will be field-checked this coming summer.

3.8 Comparison of 1:62,500 and 1:24,000 Scale LANDSAT Classifications

The 1:62,500 scale classification is considered to provide a good representation of the land cover patterns found in the Middle Park area. The increased scale of the 1:24,000 scale classification, however, does not appear to accurately provide an increase in information. In fact, the mixture problem apparently plagued the larger scale classification to a much greater extent than the smaller scale. One reason for this is that specific mixture problem areas that were misclassified at 1:24,000 were left unclassified at 1:62,500. Also, the area represented by one data point was much larger for the 1:62,500 classification

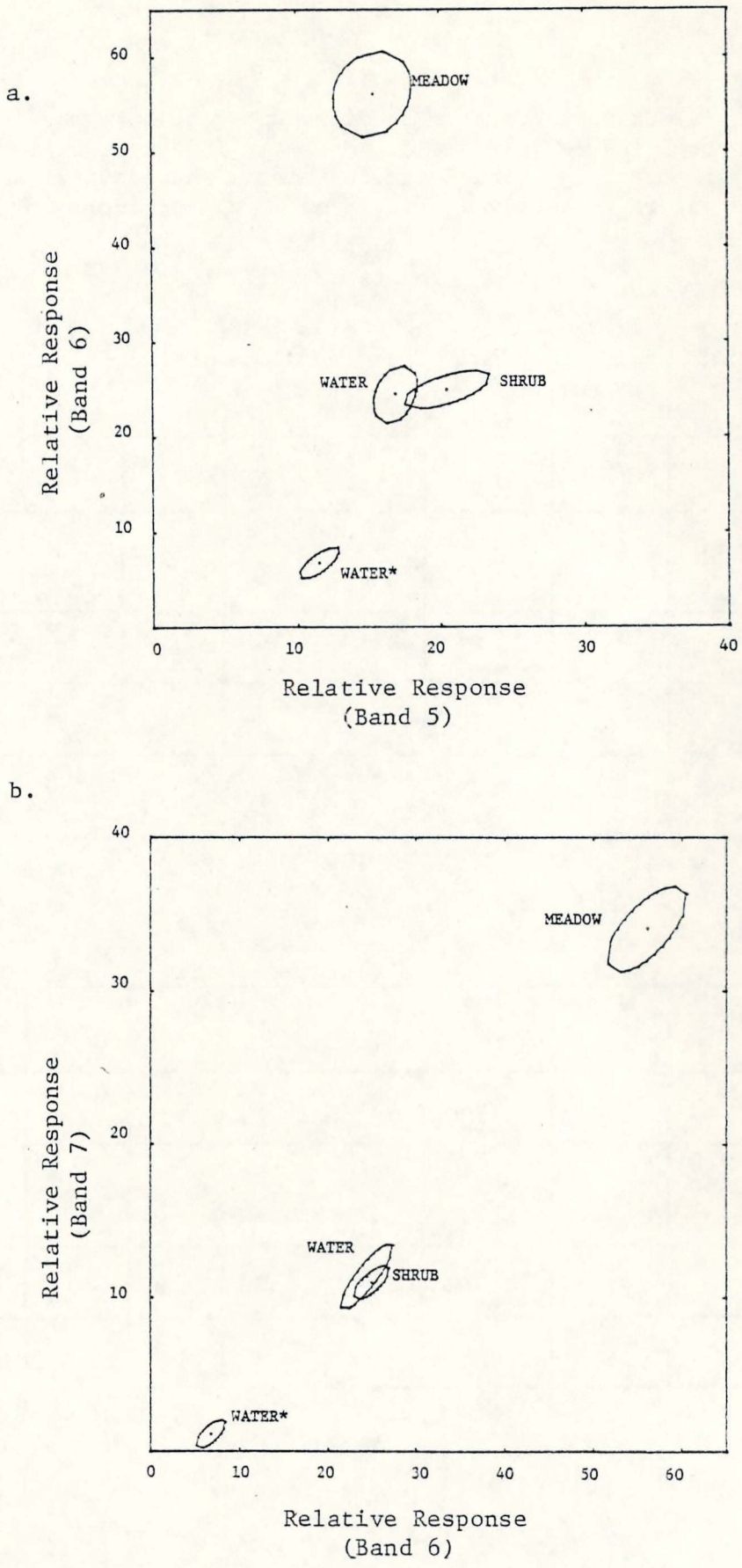


Figure 15. Ellipses of concentration for water, meadow and shrub classes for 1:24,000 scale classification in (a) bands 5 vs. 6 and (b) bands 6 vs. 7. Water signature extracted from lakes on 1:62,500 MSS data. Note the overlap between shrub and water signature extracted from the Colorado River. It appears that this overlap is due to a mixture of water and meadow along the river.

Table 3. (a) Confusion matrix showing number of points of class training sets classified correctly (diagonal elements) and incorrectly. (b) Confusion matrix showing percentage of points correctly and incorrectly classified. UC = unclassified.

(a)

Training Field	Points Classified As: Conifer	Meadow	Non-vegetated/ disturbed	Sage	Shrub	Grass	UC
CONIFER	49				32		
MEADOW		161	8	2			
NON-VEGETATED/ DISTURBED		3	22				
SAGE	3			364		19	4
SHRUB	30			3	147		

(b)

Training Field	Percent Classified As: Conifer	Meadow	Non-vegetated/ disturbed	Sage	Shrub	Grass	UC
CONIFER	60.5				39.5		
MEADOW		94.0	4.5	1.5			
NON-VEGETATED/ DISTURBED		12.0	88.0				
SAGE	1.0			93.0		5.0	1.0
SHRUB	16.5			1.5	82.0		

(8 acres vs. 1 acre) and some mixture problems (except for sharp demarcations such as shorelines) were probably averaged out.

The cost of processing the data (in both human and computer resources) was approximately the same. However, the same amount of data represented about eight times as much land area on the 1:62,500 classification.

Thus, for the purpose of providing a general land cover map, the 1:62,500 classification may be the more useful. If, however, better class signatures could be obtained and the mixture problem overcome, the 1:24,000 classification could probably provide slightly more detailed information (e.g., identify subclasses of the sage community based on density).

4.0 MULTI-LEVEL SAMPLING

The literature (Rhode and Johnson, 1976; Nichols et al., 1971; Langley et al., 1969) has shown multistage sampling in many cases to be both more accurate and less expensive than simple random sampling for estimating one or more parameters.

One such parameter that would be of interest to natural resources managers in Middle Park is the acreage of that habitat type suitable for browse by mule deer. This might include those areas classified as sage and/or mountain shrub on the maps produced. If necessary, a more precise definition of the habitat type of interest could be made by the resource managers and implemented in the classification procedure.

An example of a multistage sampling scheme proposed for Middle Park might make use of LANDSAT imagery at a scale of 1:62,500 and CIR aerial photography at a scale of 1:24,000 or a larger scale.

The first step in such an example would be to grid off the LANDSAT imagery into primary sample units (PSU's). The size and shape of PSU's is based on the amount of variation between PSU's and practical considerations such as the amount of photo interpretation needed (Rhode, 1976). For this example, assume that a PSU size of 20 x 20 pixels is chosen.

The next step is to grid off the study area into the 20 x 20 pixel PSU's. If the study area is assumed to be 1000 square miles, about 1500 PSU's would result.

Let Xi = the estimated number of pixels of shrubland suitable for mule deer browse on the i^{th} PSU. The value of Xi would equal the number of pixels in a PSU classified as the appropriate shrubland. A table

is then prepared which will show Xi and cumulative Xi,

$\sum_{i=1}^{N} Xi$, for each PSU (as an example, Table 4 is included).

To determine the number of PSU's that must be sampled, the following formula is used:

$$n = \frac{t^2 \times CV^2}{(AE)^2}$$

where:

n = # of PSU's to be sampled

t = t statistic at N-1 degrees of freedom and specified confidence level

CV = coefficient of variation = $(s/\bar{x}) \times 100$

AE = user specified allowable error in %.

For the given problem $\bar{x} = 140$. Assume s = 28. Then CV = 20. Let AE = ± 5% and the confidence level = .95. N = 1500 (number of PSU's in the population). Then t = 1.960 at N - 1 = 1499 degrees of freedom and a .95 confidence level. Thus,

$$n = \frac{(1.960)^2 \times (20)^2}{(5)^2} = 61$$

The method for selecting PSU's to be sampled is variable probability sampling with probability of sample selection proportional to the values of shrub acreage estimated in the first stage (Rhode and Johnson, 1976). The probability of selecting a PSU is:

$$p_i = Xi / \sum_{i=1}^{n} Xi$$

The actual selection of PSU's consists of preparing a list of 61 random numbers from 0 to 210,000. The PSU, whose cumulative total includes one of these random numbers, is selected for measurement in the second stage (Rhode and Johnson, 1976). Assume two of the random numbers are 522 and 1009. Then PSU's 5 ($\Sigma Xi = 532$) and 7($\Sigma Xi = 1052$) would be chosen for the sample (See Table 4).

The PSU's thus selected would then be located on the aerial photographs. Estimates of shrub acreage would be made using a dot grid overlay. A table would then be prepared showing the acreage estimated in the second stage, y_i, and the value $A_i = y_i/p_i$ (Table 5). Then the total estimated acreage of shrubland in the Middle Park Study area would be:

$$\hat{A} = \frac{1}{n} \sum_{i=1}^{n} \frac{y_i}{p_i}$$

where:

$\hat{A}$ = total estimated acreage

n = # of PSU's in sample = 61

y_i = estimated acreage of i^{th} PSU

p_i = probability of selecting i^{th} PSU

The variance, s^2, and standard deviation, s, would be:

$$s^2 = \frac{1}{n} \sum_{i=1}^{n} p_i (A_i - \hat{A})^2$$

$$s = s^2$$

The multistage sampling system described is a very simple one. Possible modifications to increase its accuracy would be to add another stage of larger scale aerial photography, or to stratify the population on LANDSAT imagery.

Table 4. List of PSU's and Number of Pixels with Shrub Classification.

PSU	Xi	$\sum_{i=1}^{n} Xi$	p_i
1	7	7	7/210,000 = .000033
2	28	35	28/210,000 = .000133
3	112	147	112/210,000 = .000533
4	84	231	84/210,000 = .000400
5	301	532	301/210,000 = .001433
6	280	812	280/210,000 = .001333
7	240	1052	240/210,000 = .001143
8	150	1202	150/210,000 = .000714
9	94	1296	94/210,000 = .000448
.	.	.	
.	.	.	
.	.	.	
.	.	.	
.	.	.	
.	.	.	
1500	122	210,000	122/210,000 = .000581

Table 5. List of Sampled PSU's and Estimates of Shrub Acreage.

Number (n)	PSU	p_i	y_i (acres)	$A_i = \frac{y_i}{p_i}$
1	5	.001433	331	230983
2	7	.001143	270	236220
3	24	.000999	230	230230
4	98	.001333	334	250526
5	111	.000714	208	291316
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
61	1472	.001428	294	205882

The benefits of such a sampling system over those using one stage of either satellite or aircraft imagery are a reduction in cost and, often, an increase in accuracy. Rhode (1976), in a specific example, shows a radical difference in standard deviation (from .9% to 11.3%) in the estimate of the same parameter between a multistage system using PPS (probability proportional to size) sampling and one using simple random sampling. And, as stated by Langley (1969), "the method (multistage sampling) has proven to yield unbiased estimates, and furthermore the sampling error depends solely on the accuracy of the predictions made at each stage. Consequently, the estimates are free of the sampling errors customarily arising by virtue of the inherent variation existing between the raw population units."

An application of multistage sampling that will be investigated intensively in the second year of the study is that of determining the accuracy of classification using LANDSAT data. It is expected that the decreased cost and increased accuracy realized in the estimation of a parameter such as acreage can also be realized in the estimation of a parameter such as percentage of correct (or incorrect) classification. Most of the computer programs required for applying multistage sampling techniques to Middle Park have been developed during the present study.

5.0 SUMMARY

This report discussed the first year's effort for Middle Park Inventory Analysis. The biomass experiment did not show a strong relationship between clipped and weighed sagebrush community biomass and ratioed spectral reflectance data. Ratioed spectral data and capacitance meter data did, however, show reasonable correlations. Computer-assisted classifications of August 15, 1975 LANDSAT MSS data were performed for the Middle Park study area at a scale of 1:62,500 and a subset of the data at a scale of 1:24,000. Overall, the 1:62,500 classification showed good general agreement with vegetation and land use cover patterns based on field studies and analysis of aerial photography. The 1:24,000 scale classification was degraded to a large extent by the presence of mixtures.

It appears that the 1:62,500 classification may be used as the first stage in a multilevel sampling scheme. Additional photographs will be obtained during July 1977, for the entire study area at a scale of 1:24,000. In addition to these broad coverage data, larger scale 70mm photographs of selected sampling units will be obtained in August 1977. Ground sampling may be carried out as a final stage. This will provide the framework for development and evaluation of multilevel sampling techniques for wide-area inventory analysis in Middle Park. Finally, further ground sampling will permit a quantitative evaluation of classification performance obtained in this study.

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Table A1. Spectral Reflectance and Capacitance Meter Biomass Data.

Plot	Spectral Reflectance Band (μm)				Relative Biomass (grams/1' x 2' plot)
	.6-.7	.675	.8-1.1	.8	
1	.112	.119	.196	.171	18
2	.110	.117	.189	.167	14
3	.067	.070	.133	.114	19
5	.101	.105	.194	.173	30
6	.107	.111	.193	.173	27
7	.113	.123	.203	.175	11
9	.112	.118	.209	.188	23
10	.122	.125	.191	.169	10
11	.118	.130	.213	.196	19
12	.103	.113	.189	.164	27
14	.104	.108	.180	.159	20
15	.103	.105	.186	.169	23
16	.117	.125	.217	.180	15
17	.104	.104	.199	.172	27
19	.091	.091	.192	.170	31
20	.110	.117	.215	.186	25
21	.098	.103	.202	.172	38
22	.115	.118	.201	.178	15
24	.089	.091	.172	.149	21
25	.100	.100	.195	.185	37
26	.112	.103	.200	.152	29
27	.123	.126	.210	.184	15
29	.085	.086	.165	.144	24
30	.119	.121	.227	.195	36
31	.138	.141	.241	.202	19
32	.102	.105	.200	.176	28

Table A2. Vegetation Type Biomass Data. Samples Were Oven Dried at 100°C for 24 Hours.

	Biomass (grams/1' x 2' plot)							
Plot	Grass	Forbs	Artr	Chvi	Syor	Putr	Tot. Shrub	Tot. All
3	7.7	1.8	3.8	0.6	0.7	-	5.1	14.6
8	5.6	0.2	6.1	-	-	-	6.1	11.9
13	1.2	3.4	0.5	-	-	-	0.5	5.1
18	5.0	3.5	8.7	1.0	-	-	9.7	18.2
23	6.6	0.3	5.5	3.7	-	-	9.2	16.1
28	3.1	2.2	14.7	-	-	-	14.7	20.0
33	3.0	3.9	-	0.8	-	-	0.8	7.7
38	2.1	1.2	5.4	-	-	-	5.4	8.7
43	26.6	0.6	0.3	1.0	-	-	1.3	28.5
48	2.5	1.0	7.7	0.2	-	1.9	9.8	13.3
53	9.6	0.4	-	1.6	-	-	1.6	11.6
58	3.6	1.2	9.0	-	-	-	9.0	13.8
63	6.5	1.4	0.9	-	-	-	0.9	8.8
68	5.6	-	14.0	-	-	-	14.0	19.6
73	14.9	6.4	0.2	-	-	-	0.2	21.5

Artr = Big sagebrush

Chvi = Green rabbitbrush

Syor = Snowberry

Putr = Bitterbrush